UCRL-JC-126315 Abs

Low defect mask blanks for extreme ultraviolet lithography

S.P. Vernon, P.A. Kearney, R.A. Levesque
Lawrence Livermore National Laboratory
PO Box 808, Livermore, CA 94551

Reflection masks for extreme ultraviolet lithography (EUVL) consist of a high reflectance multilayer (ML) coated substrate (mask blank) that is overcoated with a patterned absorber layer. Any reflectance variation in the mask constitutes a potential mask defect. The ML reflective coating operating at 13 nm consists of 40 layer pairs of 4 nm of Si and 3 nm of Mo capped with a 30 nm Si protective layer. As with all other advanced lithography systems, mask defects can represent a fundamental limitation to the practical implementation of the technology. In EUVL, the deposition of the ML coating with low defect density represents an enabling technology for EUVL.

Operation of prototype EUVL systems with a no mask defects requires defect densities of less than $0.1/cm^2$ @ ≥ 0.13 µm. In a study completed in 1994, typical particle counts in sputtered Mo/Si MLs were of order $10{,}000/cm^2$ @ ≥ 0.25 µm, *five orders of magnitude* greater than is required for prototype work. We recognized that the semiconductor industry has developed highly refined procedures for the deposition of low defect density, single component films utilizing magnetron sputtering technology. However, extension of these techniques to the fabrication of highly uniform Mo/Si MLs is not straightforward. In fact, the range of deposition parameters associated with low defect generation is generally inconsistent with the requirements for high quality ML fabrication[1]. As a result, we have developed a new deposition tool using ion beam sputter deposition (IBSD). This method offers several advantages in comparison to magnetron sputtering that are consistent with low defect generation: (1) low deposition pressure, (2) low temperature operation and (3) electrical isolation of the substrate and sputtering target.

IBSD Mo/Si ML coatings were grown on 150 mm diameter Si wafers. Wafers are employed as substrates because of their extreme smoothness and because of the availability of appropriately clean wafers and compatibility with standard semiconductor diagnostic tools. Standard mechanical interface (SMIF), a class <1 minienvironment and ultra-low particle transfer robots protect the blank from environmental contamination during handling. Carefully controlled pump/vent protocols developed with feedback from *in situ* particle monitors minimize wafer contamination during wafer introduction and deposition. A Tencor 6420, dark field defect detection system, was used to measure the coating defect density.

The defect density includes all particles greater than 0.13 µm in diameter. A 15 mm exclusion zone is used resulting in a deposition area of 113 cm^2. The coatings were all 81 layers of Mo/Si. As expected, the defect contribution from the wafer handling was insignificant. Total defect densities as low as 0.027 cm^{-2} or three paritcles per wafer were measured. The added defect density was 0.018 cm^{-2} or 2 particles per wafer. These results represent a significant advance in the prospects for the practical implementation of EUVL.

[1]S. P. Vernon, D. G. Stearns, and R. S. Rosen, Applied Optics 32, pp. 6969-6974 (1993).

*Work performed under the auspices of the U. S. Department of Energy by the Lawrence Livermore National Laboratory under contract no. W-7405-Eng-48.